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A REVIEW OF THE USE OF CONTACT INSECTICIDES TO CONTROL POST-HARVEST INSECT INFESTATION OF FISH AND FISH PRODUCTS

by

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PREPARATION OF THIS REVIEW

Although the use of insecticide to prevent insect attack during fish drying is widespread throughout the world no systematic review has previously been undertaken of investigations by entomologists and fish technologists. It was decided to bring this information together as a basis for future studies and possible legislation. The review will also be a useful training-aid in FAO Fish Technology training programmes, such as the FAO/DANIDA project GCP/INT/391/DEN, which has provided the funds for printing.

ABSTRACT

Contact insecticides are widely used to control infestations of fresh and cured fish by blowflies and beetles. Past and present usage are reviewed. Approximately thirty insecticides have been used at some time to disinfest fish. Of these only two have had internationally accepted maximum residue levels established on fish by the FAO/WHO Joint Meeting on Pesticide Residues. These are pyrethrins synergised with piperonyl butoxide, and pirimiphos-methyl. Results of recent analytical studies indicate that the former may not be suitable for safe and effective use in warm climates. Additionally, in many countries there is widespread, indiscriminate and dangerous use of non-approved insecticides. There is a clear need for fisheries technologists to have a better understanding of insecticides, and for more research to be undertaken into the safe usage of insecticides for the protection of fish.

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1. INTRODUCTION

Fish that is being processed into more durable forms commonly suffers from infestation by blowflies and beetles. The former belong to the order of insects Diptera and infest wet fish prior to and during processing. The beetles belong to the order Coleoptera and attack cured or dried fish and fish products. Whilst fish processors have long recognized the need to combat these insects, they have until recently been hindered by the absence of safe and efficacious techniques. Although every effort must be made to avoid the unnecessary use of insecticides, it is clear that in many instances there are no non-chemical procedures which offer an effective and economically viable alternative. A literature survey was conducted to locate published references to the use of insecticides on either fresh or cured fish or their products; earlier reviews having been undertaken by Blatchford (1962), Taylor and Proctor (1979), FAO (1981), and Taylor (1982). There is still very little information available because of the long standing reluctance of some fisheries technologists to use insecticides publically and the general lack of attention paid in the past to the fisheries post-harvest sector. Entomologists have rarely given adequate information concerning the types of fish being attacked and fisheries technologists have paid a similar lack of attention to the identification of the blowflies and beetles causing the infestation. The main reason for this is that the application of contact insecticide to fish does not fall within the established disciplines of fish technology or agricultural entomology. Hence most fish technologists are taught very little about insects and their control and just as few entomologists have experience in post-harvest fish technology. There has been a great deal of indiscriminate and dangerous usage in many countries because of the absence of clear recommendations for the control of insects and a lack of training in the nature and correct use of insecticides. The data which have been published are often incomplete and furthermore they frequently relate to different species of fish insect, thus it can be difficult to make meaningful comparisons. Whilst there has been limited use of fumigants and inert gases to control insects, this report is confined to the use of contact insecticides.

The first record of a modern contact insecticide being used on fish is that of synergized pyrethrins in 1959 in Northern Rhodesia (Olley, 1961; Blatchford, 1962). Since then almost thirty insecticides have been evaluated in laboratory or field trials, or have been observed in use in the field. Many are only mentioned once or twice in the literature and appear never to have been considered for serious use in the field. Most of the work has centred on the use of pyrethrins, which are normally synergized to some extent by pyperonyl butoxide. The other two insecticides which have received a great deal of attention and use are pirimiphos-methyl and tetrachlorvinphos. However, it is important to realize that no insecticide is completely safe. All of them can be dangerous if they are misused and most are totally unsuited for use with edible commodities. Fortunately there are a few contact insecticides which are considered suitable internationally for use with post-harvest food commodities. This small group comprises those which, whilst capable of giving good insect control, have also a low mammalian toxicity and thus should not therefore, present a potential hazard to the consumers of the treated fish. Unfortunately much of the development work has concentrated on the efficacy of insecticidal treatments and the resulting financial benefits while very little attention has been paid to aspects of safety for the consumers of treated fish. It is important to ensure that the use of insecticides does not make production easier for the processor at the expense of creating toxicological problems for the consumer.

When assessing the possible hazards associated with use of insecticides on food commodities it is important to know the level of residue present in the final product (Halliday, 1986). Unfortunately, many published accounts of the use of insecticides on

fish do not include details of residues being concerned only with the efficacy of the treatment. Furthermore, it is accepted that there were many problems in accurately determining levels of pyrethrins in fish in the 1960's and early 1970's. Analysis of low levels of insecticides in fish can still present considerable technical difficulties and it could be for this reason, together with the substantial costs involved, that so few residue analyses have been undertaken.

The first two sections of this review concern the insecticides which have been applied to control blowfly infestation of wet fish and beetle infestation of dried or cured fish. The third section deals with the insecticides which have been used to treat packaging material. Where enough information is available comment has been made on the suitability of the compounds. Further information on insects and insecticides is given in Appendices 1 and 2 respectively. Studies involving the post-harvest application of insecticides on fish are often extremely difficult to locate and it may be that there are other published and unpublished reports which were not identified during the course of this review.

2. INSECTICIDES APPLIED TO WET FISH TO COMBAT BLOWFLY INFESTATION

2.1 Synergized pyrethrins

The first application was by Olley (1961) who used pyrethrins synergized with piperonyl butoxide (ratio 1:10) to control blowfly infestation of herring in a UK factory prior to their processing into fish meal or oil. An emulsion of 0.3 per cent pyrethrins (3 per cent piperonyl butoxide) was sprayed every two or three days onto piles of loose fish at a rate of 1 litre/41 m^2 of surface area. This treatment did not inhibit oviposition but did prevent the hatching of larvae.

Somme and Gjessing (1963) conducted a series of laboratory and field trials in Norway to evaluate different insecticides for the control of Calliphora vicina Rob.Desv. and other Calliphoridae in stockfish. Synergized pyrethrins (1:10) were found to have a marked repellent effect and to give very good larval control when the fish were dipped for thirty seconds in an emulsion containing 0.12 per cent active ingredient. Chemical analyses of cod, saithe and haddock carried out two and a half to five months after treatment indicated residues of pyrethrins in the range of 1 to 8 mg/kg. However, no analyses for residual piperonyl butoxide were carried out. The samples of cod and saithe analysed by bioassay techniques five months after treatment appeared to contain less than 1 mg/kg of pyrethrins. The authors accepted the lower figure and concluded that the residues of pyrethrins were too small to represent any danger to consumers. Similar work in Uganda (McLellan, 1963) demonstrated that dipping Tilapia spp. for one or two seconds in an emulsion containing 0.125 per cent synergized pyrethrins (1:10) achieved a major reduction in infestation by Chrysomya marginalis Wied. during subsequent drying. McLellan draws attention to the problem of analysing cured fish for low levels of pyrethrins and presents no data on residue analysis. It was concluded, however, that the treatment did not present any hazard to consumers. In South Arabia, Green (1967) found that dipping dry fish for 30 seconds in 0.02 per cent synergized pyrethrins (1:4) was not effective against infestation of Wohlfartia sp. but a higher concentration of 0.16 per cent gave very good control. No residue data were presented.

In Canada, Morris and Andrews (1968) investigated the use of synergized pyrethrins (1:2) to control infestation of light-salted cod by Calliphora terraenovae (Macq.). They achieved good control by dipping fish for three to five seconds in an emulsion containing 0.062 per cent pyrethrins. Residues of pyrethrins three weeks after a 0.125 per cent application ranged from 0.3 to 0.8 mg/kg. On the basis of the Canadian work further analyses were conducted (FAO/WHO, 1970) in which for the first time levels of the synergist

were determined. Dried cod, five weeks after treatment of the freshfish, was found to contain mean residues of 0.06 mg/kg pyrethrins and 0.87 mg/kg piperonyl butoxide. On the basis of these results the FAO/WHO Joint Meeting on Pesticide Residues (JMPR) recommended temporary Maximum Residue Levels (MRLs) on dried cod fish of 0.1 mg/kg pyrethrins and 1.0 mg/kg piperonyl butoxide (FAO/WHO, 1970). In 1972 the JMPR considered further data from work with dried cod in Norway and found it appropriate to increase the tolerance on dried fish to the levels already given for raw cereals, i.e. 3 mg/kg pyrethrins and 20 mg/kg piperonyl butoxide (WHO, 1973).

Kordyl (1977) conducted preliminary trials with the use of synergized pyrethrins in Tanzania. Rogers (1976) and Meynell (1978) reported on work conducted over several years in Malawi in which various methods of applying synergized pyrethrins to small whole fish to control Chrysomya spp. were evaluated. Spraying, dipping and hosing with different levels of active ingredient gave satisfactory control of the blowflies but produced residues which were later determined to be well in excess of the established MRLs (Walker, 1981). Diouf (1980) dipped fish of various types and sizes in emulsions of synergized pyrethrins (1:10) for between five and ten seconds in Senegal. He obtained good control of blowflies with a concentration of 0.0625 per cent but although mean residues of pyrethrins were acceptable, those of piperonyl butoxide were well in excess of 20 mg/kg. It was subsequently established in Malawi that small whole Cichlidae could not be adequately protected against blowfly infestation either by spraying (Walker and Donegan, 1984) or by dipping (Anon, 1984) without exceeding the MRLs.

The results of the recent work indicate that it is very doubtful whether synergized pyrethrins can be used safely on drying fish in tropical countries. This information arises from trials in the tropics which included much improved methods of chemical analysis. Perhaps it is not surprising that the outcome is different from earlier experimental work conducted for local industries in temperate Norway and Canada with much less accurate analytical techniques.

2.2 Tetrachlorvinphos

Morris and Andrews (1968) included both wettable powder and emulsifiable concentrate formulations in their trials in Newfoundland, Canada. Results were conflicting in that dipping for 3 to 5 seconds in a 1.0 percent emulsion was effective whereas dipping in a similar strength suspension prepared with wettable powder was ineffective. The relative merits applying insecticide to fish by means of emulsions and suspensions have still not been resolved.

Tetrachlorvinphos, wettable powder, was evaluated in Malawi both as spray (Walker and Donegan, 1984) and dip applications (Anon. 1984). Spray treatments of 0.1 percent active ingredient achieved larval control of at least 95 percent when used with small whole Cichlidae and resulted in a mean residue of 2.7 mg/kg. Dipping the fish in a 0.043 percent preparation resulted in 99 percent control of larvae and residues of less than 5 mg/kg. No MRLs have been established for tetrachlorvinphos on any food commodities because the manufacturers have not submitted the data required by WHO for toxicological clearance.

2.3 Pirimiphos-methyl

Pirimiphos-methyl was tested extensively in Malawi for the control of Calliphoridae and Sarcophagidae infesting sun-drying small whole Cichlidae. After an unsatisfactory attempt to use a dilute dust (Walker, 1981) work centred on the use of dilute emulsions. Good larval control was achieved by a spray application of pirimiphos-methyl at 0.2 percent which resulted in residues of 9.5 mg/kg (Walker and Donegan, 1984). Excellent larval

control was also obtained by dipping the fish for one minute into a dilute emulsion containing 0.068 percent active ingredient. Residues were found to be less than 5 mg/kg (Anon. 1984).

On the basis of this work pirimiphos-methyl was used on a pilot-scale in Malawi and was later given formal clearance in 1982 by the Government of Malawi for use on fish throughout the country (Anon. 1984). The insecticide is now in routine use in Malawi for control of blowflies infesting sun-drying Haplochromis spp. and Lethrinops spp., by spraying and dipping, particularly in the wet season.

A preliminary attempt to extend the use of an emulsion containing 0.06 percent to large split Tilapia spp. in Malawi showed that it resulted in unacceptably high residues (Walker, 1984). Full scale field trials conducted in the Gambia (Walker and Evans, 1984) established that an immersion of bonga, Ethmalosa fimbriata, for one minute in a more dilute dip containing 0.03 percent pirimiphos-methyl gave complete control of Chrysomya spp. and Lucilia sericata Mg. The residue of 5.1 mg/kg in the dried fish was considered acceptable. A survey conducted in the Gambia (Walker and Evans, 1984) established that pirimiphos-methyl was already being used commercially by fish processors to protect drying fish. Recent trials in Indonesia (Esser et al, 1986) have established that treatment of marine catfish, Arius spp., with a pirimiphos-methyl dip of 0.03 percent markedly reduced infestation by Chrysomya megacephala (F.) during sundrying. The mean residue after drying was a similar 4.6 mg/kg.

Maximum residue limits for pirimiphos-methyl had previously been established on forty different types of food commodities (FAO, 1983). The submission of data concerning its use on fish in Malawi and the Gambia, together with results of additional laboratory trials (TDRI, unpublished), has resulted in an MRL of 10 mg/kg on dried fish being recommended by the JMPR in 1985 (FAO, 1986).

2.4 Other Insecticides

2.4.1 Alphacypermethrin

This is a recently developed synthetic pyrethroid which has proved effective for the protection of marine catfish, Arius sp., in Indonesia against infestation by C. megacephala and Lucilia cuprina (Wied.) (Esser et al., 1985). Fish dipped for a few seconds in concentrations of 0.001 and 0.006 percent contained residues of up to 0.25 mg/kg and 1.3 mg/kg respectively after a storage period of seven days (Esser et al 1986). At present no data have been submitted to JMPR to enable either an acceptable daily intake (ADI) or MRL to be recommended.

2.4.2 Malathion

Dipping for 30 seconds in an emulsion of 0.72 percent malathion provided good protection for a cod and haddock from blowfly attack in Norway, but the resulting mean residue was 65 mg/kg (Somme and Gjessing, 1963). Green (1967) evaluated malathion to combat Wohlfartia sp. infestation of drying fish in South Arabia. A dip in 0.5 percent active ingredient emulsion gave effective control but a lower concentration of 0.125 percent did not. Residues for the higher concentration four weeks after application were 64 mg/kg in tuna and 32 mg/kg in rockfish, Nemipterus japonicus. These residues are very high and were considered to be unacceptable.

No further investigations have been conducted with malathion to control blowfly infestation of fish. However, Walker and Evans (1984) did record the use of a dilute dust mixture of malathion and fenitrothion by some traditional processors in the Gambia.

2.4.3 Dichlorvos

Cod dipped for three to five seconds in a preparation of 0.5 percent dichlorvos was pretected effectively against blowfly infestation (Morris and Andrews, 1968). No residue analyses were undertaken. Aerosol preparations containing dichlorvos have been reported as being used by processors in Malawi (unpublished 1984) and in Indonesia (Esser et al,1985). It is now generally accepted that this insecticide is too acutely toxic for use on food commodities. Azeza (1986) claimed that extension campaigns have successfully reduced the use of aerosols containing dichlorvos by processors at Lake Chad in Nigeria.

2.4.4 Propoxur

This carbamate compound was reported by Wood (1983) as being used in dilute dust form by processors in The Gambia. It was also reported to be in widespread use in Indonesia in an aerosol mixture with dichlorvos (Esser et al,1985). It is generally accepted that propoxur is not suitable for use on food commodities.

2.4.5 Miscellaneous

Fourteen other compounds have been reported on a few occasions. They were either evaluated in experimental trials and considered unsuitable for one reason or another, or they were observed being used by local processors against the advice of the regulatory authorities. They are: bioallethrin (Walker, 1986), chlorbicyclen (Somme and Gjessing, 1963), chlorpyrifos and coumaphos (Morris and Andrews, 1968), cypermethrin (Walker, 1986), DDT (Somme and Gjessing, 1963; Diouf, 1980; Walker, 1984), demeton and diazinon (Somme and Gjessing, 1963), dimethoate (Walker, 1986), fenchlorphos (Somme and Gjessing, 1963; Morris and Andrews, 1968), fenitrothion (Walker and Evans, 1984), lindane (Mastaller, 1981), dipropyl pyridine-2, 5-dicarboxylate (Somme and Gjessing, 1963) and trichlorphon (Somme and Gjessing, 1963; Morris and Andrews, 1968).

3. INSECTICIDES APPLIED TO DRIED OR CURED FISH TO COMBAT BEETLE INFESTATION

3.1 Synergized Pyrethrins

The first recorded usage was in Northern Rhodesia (Zambia) in 1959, variously reported by Olley (1961) and Blatchford (1962), when dilute dust preparations were successfully applied to protect dried fish from Dermestes frischii Kugelann for three or four months. Galichet (1960) conducted some preliminary laboratory experiments to control beetles with synergized pyrethrins at Lake Chad. Rollings et al (1963) used synergized pyrethrins (1:10) in trials to protect dried fish (Pseudotolithus typus) in Nigeria. It was applied at a dosage of 5 mg/kg, but failed to give effective control. Initial tests in Kenya with a dust formulation did not achieve effective control of Dermestes maculatus Degeer on Tilapia spp. and hence the main emphasis was placed on developing a dipping application (McLellan, 1964). Effective control of the beetles was achieved by dipping, for an unspecified time, in an emulsion of 0.018 percent synergized pyrethrins (1:2). No increase of effectiveness was achieved by increasing the proportion of the synergist to 1:10. No residue analyses were undertaken. Data from Mali (unpublished, 1966) indicated that satisfactory control of D. maculatus and Necrobia rufipes (Degeer) had been achieved by dipping dried fish in 0.02 percent synergized pyrethrins (1:10).

Green (1967), working in South Arabia, evaluated synergized pyrethrins as a means of controlling D. frischii infestation of dried fish. Dust applied at a dosage of 15 mg/kg (1:16) did not give effective protection. Good control was obtained however, when various types of stored fish were dipped for two seconds in a 0.02 percent emulsion of synergized pyrethrins (1:4). A similar treatment applied to fresh fish prior to drying or to fish which had been dried immediately before treatment gave poor protection during subsequent storage. No determinations were made of the residues.

As mentioned in Section 2.1, temporary MRLs for pyrethrins and piperonyl butoxide were set in 1969 at 0.1 mg/kg and 1.0 mg/kg respectively (FAO/WHO, 1970), and later increased to 3 mg/kg and 20 mg/kg (WHO, 1973).

Proctor (1972) evaluated dust and dip applications to dried fish in Zambia to control Dermestes ater Degeer and D. maculatus. Dust (1:16) applied at 300 mg/kg gave poor protection but dipping in 0.018 percent synergized pyrethrins (1:2) prevented infestation for eight to twelve weeks. No residue analyses were conducted. Kordyl (1977) followed the guidelines established earlier by McLellan and investigated the use of synergized pyrethrum in Tanzania. He did not report procedural details but stated that protection began to fail after two weeks and at four months all samples were heavily infested with dermestid beetles. Further work in Senegal by Diouf (1980) demonstrated that dipping in 0.063 percent synergized pyrethrum (1:10) produced acceptable control for up to two months. Residue analysis data indicated that whilst the mean pyrethrins level of 1.2 mg/kg was within the established tolerance that of piperonyl butoxide was an excessively high 73 mg/kg.

Unpublished reports indicated that dip applications of synergised pyrethrins are in common use in Kenya, Senegal and Zimbabwe and hence this treatment was included when work was conducted at Lake Turkana, Kenya by Golob et al (1986) to evaluate a range of insecticides. Good control of D. maculatus was achieved by an immersion for four seconds in a 0.018 percent emulsion of synergized pyrethrins (probably 1:10). Residues, even after six months, were found to be 5.7 mg/kg for pyrethrins and 225 mg/kg for piperonyl butoxide. These are far in excess of the accepted MLRs and are totally unacceptable. Despite these problems synergized pyrethrins are still being recommended for use in Nigeria (Azeza, 1986).

As with application for blowfly control it does not now appear that synergized pyrethrins can be used effectively and safely for control of beetle infestations.

3.2 Tetrachlorvinphos

Guillon (1976) conducted comprehensive trials in Mali to counter infestation of dried fish with D. maculatus and N. rufipes. It was found that a dip of one minute in suspensions containing 0.0375 percent, 0.075 percent and 0.1125 percent active ingredient reduced damage levels by 80 percent, 91 percent and 93 percent respectively. Residue data, (unpublished), available for the two lowest concentrations indicated that whilst 0.075 percent may give rise to residues slightly in excess of 10 mg/kg after 39 days, those obtained from the 0.0375 percent treatment produced levels of less than 5 mg/kg after 11 days. As a result of this work and an active extension campaign, the use of tetrachlorvinphos at a concentration of 0.0375 percent became widespread in Mali. Duguet et al (1985) included a dipping treatment of longer duration in his evaluation of three insecticides in the same country and demonstrated that it gave excellent protection of Sarotherodon niloticus against D. maculatus for 60 days but provided greatly reduced control after 90 days. Bouare (1986) conducted trials in Niger in which smoked fish were dipped or sprayed with preparations of 0.05 and 0.1 percent active ingredient. The results of spray applications were promising but somewhat inconclusive.

At present no internationally accepted maximum residue levels have been established for tetrachlorvinphos but several countries consider it safe to use on fish and grain up to a residue limit of 10 mg/kg. Azeza (1986) reported that a residue level of 28 mg/kg was detected in a trader's sample of Lates niloticus from Lake Chad. Commercial samples of dried fish from Zambia analysed at TDRI in 1985 had a mean residue of 202 mg/kg. These levels are clearly excessive and could present a considerable hazard to the consumer. They are the result of either accidental or deliberate misuse of the insecticide and illustrate the need for some form of regulation or supervision.

3.3 Pirimiphos-methyl

Laboratory trials in the UK investigated the use of this insecticide, amongst others, for the control of D. maculatus on smoke-dried shad (Taylor and Evans, 1982). A dip for three seconds in a concentration of 0.00625 percent produced initial residues of 9 mg/kg. This treatment did not give complete control of the insects but did achieve a significant reduction in weight losses. Following on from the laboratory work Taylor (1981) investigated the use of pirimiphos-methyl to control D. maculatus at Lake Chad in Nigeria. Various types of dried fish were dipped in a suspension of 0.0125 percent and good insect control was recorded for up to three weeks.

Unpublished reports from Malawi indicated that good control of D. maculatus could be achieved by use of this insecticide and it was therefore included in large scale field trials conducted in The Gambia (Walker and Evans, 1984). Pieces of dried shark were dipped for five seconds in emulsions of 0.03 percent and 0.015 percent pirimiphos-methyl. The higher level produced a residue of 9.7 mg/kg immediately after application and good control of insects was achieved for one month in storage. After this time the protection was reduced and after three months the mean residue was 1.0 mg/kg.

A series of trials conducted in Mali to control infestation of different types of fish by D. maculatus and D. frischii demonstrated that although pirimiphosmethyl was more effective than tetrachlorvinphos it was also more expensive locally (Anon, 1984a). Duguet et al (1985) working in the same country demonstrated that S. niloticus dipped for ten minutes in a concentration of 0.05 percent received good protection for 120 days, after this period insect numbers began to increase. No residue data was presented for either study. Golob et al (1986) demonstrated in Kenya that dried Tilapia spp. dipped for four seconds in 0.01 percent emulsion of pirimiphos-methyl received protection in store for two months against D. maculatus. Residues were determined to be 8.1 mg/kg after one week.

Esser et al (1986) demonstrated that marine catfish, Arius spp., were protected from infestation by Dermestes spp., for ten weeks following a dip application in an emulsion of 0.03 percent. Residue immediately after treatment was 4.6 mg/kg.

As a result of studies undertaken in Malawi, The Gambia, and UK, and MRL of 10 mg/kg was recommended for pirimiphos-methyl on dried fish (FAO, 1986). There is a need to publicise this information and advise processors on correct application techniques because commercial samples of dried fish from Zambia analysed at TDRI in 1985 contained an excessively high residue level of 26 mg/kg.

3.4 Malathion

Green (1967) established in South Arabia that dried fish dipped in an emulsion frischii for several weeks. Residues after four weeks were variable, being highest in catfish (24 mg/kg) and totally absent in shark. In Zambia, Tilapia spp., dipped by Proctor (1972)

in an emulsion containing 0.125 percent were protected from D. maculatus and D. ater for eight weeks but after this period there still remained residues of up to 43 mg/kg. It has not yet been established that malathion can give good control of dermestid beetles without creating unacceptable levels of residue. However, Guggenheim (1980) reported limited use of malathion by some fish processors in Senegal.

3.5 Deltamethrin

Pieces of dried shark dipped for five seconds in 0.03 percent deltamethrin contained residues of 1.6 mg/kg immediately after treatment and 0.9 mg/kg after three months storage in The Gambia (Walker and Evans, 1984). Good control of D. maculatus was achieved and weight losses were greatly reduced.

Duguet et al (1985) evaluated the use of dips containing both synergized (1:10 piperonyl butoxide) and unsynergized deltamethrin in Mali. A concentration of 0.0025 percent gave excellent control of D. maculatus and N. rufipes for up to 120 days. The inclusion of the synergist did not appear to increase the efficacy. No residue data were presented. Trials in Kenya (Golob et al, 1986) also demonstrated good control of D. maculatus when Tilapia spp. were dipped for four seconds in a concentration of 0.001 percent. Residues were 1.0 mg/kg after six months when control was still effective. No residue data were presented for the piperonyl butoxide probably present at a reatio of 1:10. Much more work needs to be undertaken but it is possible that deltamethrin could prove to be a suitable insecticide for use with dried fish.

3.6 Fenitrothion

Trials in The Gambia (unpublished, 1972) demonstrated that both spray application of 0.125 percent concentration and a two second dip in 0.025 percent concentration gave adequate control of D. maculatus and D. ater infesting smoke-dried E. fimbriata. No residue analyses were undertaken. Further trials were conducted in The Gambia by Walker and Evans (1984) in which dried shark was dipped for five seconds in 0.03 percent emulsion. A residue of 9.2 mg/kg was present after one day but this decreased to 0.9 mg/kg after one month. The fall in residue was reflected by a rapid decline in efficacy against D. maculatus. The authors reported the use of a dust containing a mixture of 1.5 percent malathion and 1.2 percent fenitrothion by artisanal fish processers in The Gambia.

A similar but slightly slower fall in level of active ingredient was demonstrated in Kenya by Golob et al., (1986), who immersed Tilaplia spp. for four seconds in wettable powder and emulsion preparations of 0.01 percent. A residue after one week of approximately 9 mg/kg decreased after one month to less than 3 mg/kg. The efficacy reduced progressively and although adequately protection against D. maculatus was provided for up to two months the treatment was ineffective after six months.

3.7 Iodofenphos

One percent dust applied at a rate of 75 g/m^2 was reported to give good control of D. maculatus and D. ater in The Gambia (unpublished, 1972). Golob et al (1986) included a wettable powder formulation in field trials in Kenya. Tilapia spp. dipped for four seconds in 0.01 percent suspension were protected against D. maculatus for only one month whereas those treated in 0.02 percent were very well protected for two months. Residues after one month from both applications averaged approximately 6 mg/kg.

3.8 Permethrin

Taylor and Evans (1982) obtained poor control of D. maculatus in laboratory trials when shad were dipped for three seconds in suspensions of 0.0125 and 0.00625 percent concentration. Residues after five weeks were found to be approximately 6 mg/kg for both treatments. There were indications however, that permethrin had a repellent effect on insects. A subsequent preliminary field trial in Nigeria (Taylor, 1981) in which different types of dried fish were dipped for three seconds in 0.0125 percent resulted in a more acceptable level of control of D. maculatus. Walker and Evans (1984) conducted field trials in The Gambia in which permethrin synergized with piperonyl butoxide (1:5) was evaluated for control of D. maculatus on dried shark. The fish was dipped for five seconds in suspensions of 0.003 and 0.006 percent concentration. Residues one day after dipping were 0.8 and 2.6 mg/kg respectively. Good control was achieved for one month.

3.9 Miscellaneous

3.9.1 Bioresmethrin

Trials conducted in Mali (Guillon, 1976) failed to achieve satisfactory control of D. maculatus. Unpublished results showed that the fish had been dipped for an unknown time in an emulsion of 0.025 percent. It was later stated (Anon, 1984a) that its use had been discontinued because of high cost and toxicity.

3.9.2 Chlorpyrifos-methyl

Shad dipped for three seconds in an emulsion of 0.00625 percent were protected for up to one month against D maculatus. Residues were 25 mg/kg immediately after application and 3.4 mg/kg after five weeks (Taylor and Evans, 1982). A preliminary field trial in Nigeria (Taylor, 1981) indicated that acceptable control could possibly be achieved by dipping in an emulsion of 0.0125 percent.

3.9.3 DDT

This insecticide is not suitable for use on foodstuffs because it is a member of the organo-chlorine group which can possibly accumulate in the body tissue of consumers. Wood (1982) reported that processors in Senegal had been stopped from applying it to cured fish. However, it was suspected of still being used in Mali (Anon, 1984a) and at Lake Chad in Nigeria (Azeza, 1986).

3.9.4 Dichlorvos

A trial conducted in Botswana (unpublished, 1969) showed that pieces of paper treated with dichlorvos were effective in controlling D. maculatus when sealed with dried bream in a plastic sack. Aerosols containing dichlorvos were observed being used by fish processors in northern Nigeria (Taylor, 1981). This insecticide is not thought suitable for use with food commodities because of its toxicity.

3.9.5 Diflubenzuron

Golob et al (1986) demonstrated that moderate control against D. maculatus could be achieved for six months in Kenya by dipping dried Tilapia spp. in a 0.01 percent suspension. Residues after six months were 27 mg/kg.

3.9.6 Lindane

Fish processors in Mali used this organo-chlorine insecticide but it resulted in several instances of poisoning (Daget, 1966). The use of lindane on dried fish in Nigeria has been reported by Azeza (1977 and 1986) and Taylor (1981). Both authors recommended that its use should be discouraged. It was also reported to be used in Niger (Guggenheim, 1980).

3.9.7 Methacrifos

Good control of D. maculatus was achieved for one week in a laboratory trial in the UK in which marine shad were dipped for three seconds in an emulsion of 0.00625 in the UK in which marine shad were dipped for three seconds in an emulsion of 0.00625 percent (Taylor and Evans, 1982). The residue immediately after treatment was 23 mg/kg.

3.9.8 Phosalone

Chakrabarti, Roy and Majumder (1979) established that an application rate of 70 mg/kg protected dried Bombay duck from attack by Lasioderma serricorne (F.). Washing and cooking the fish reportedly reduced the residues to negligible (unspecified) levels.

4. INSECTICIDES USED TO TREAT DRIED FISH PACKAGING MATERIAL

The first reported use of insecticide to control insect infestation of fish was as an application to the packaging material; presumably because it was considered to be safer than treatment of the fish itself. Nonaka (1952) recorded the successful use in Japan of gamma-HCH being applied to the inner surfaces of containers holding smoked and dried fish to control Dermestes coarctatus Harold and Necrobia ruficollis (F.). Pillai (1957) treated the outer surfaces of gunny bags in India with a preparation of pyrethrins. Mallamaire (1957) working in West Africa recommended either soaking the mats used to wrap fish with a preparation of 0.6 percent DDT or dusting the outsides of the bales with 10 percent DDT or 0.6 percent gamma-HCH at a rate of 10 g/m^2. The target insects in this instance were D. maculatus, D. frischii, and N. rufipes. Galichet (1960) achieved good control of D. maculatus infesting fish in jute sacks which previously had been treated with gamma-HCH.

Blatchford (1962) reviewed the information available and cautioned that fish in contact with treated jute sacking could become contaminated with insecticide and there were therefore the two hazards of residue and taint. It was suggested that these problems could be avoided by the use of a polythene liner. Rollings and Hayward (1963) reported work planned in Nigeria to ascertain the insecticidal activity of lindane impregnated on paper and cardboard against D. maculatus. Paper treated with synergized pyrethrins did not appear effective against this beetle but was suspected of having a repellent effect.

Matting treated with HCH was claimed to protect dried Alestes spp. from infestation by dermestid beetles for up to a year in Cameroon and Chad (Daget, 1966). It was stated that this practice was enforced by a government order insisting on the use of the insecticide to treat dried fish moving between certain locations in Chad.

Valsan (1968) applied a 3 percent solution of HCH, containing vinyl acetate at 0.05 percent as an adhesive, to the external surfaces of gunny bags and also to wooden boxes containing dried tuna in India. The treatment, developed in Japan by Nonaka (1955), achieved satisfactory control of insects but imparted a taint to the product. In Mali, Szabo developed the work of Mallamaire (1957) and recommended the large scale use of a mixture of HCH (10 percent) and DDT (7 percent) for spraying the outside surfaces of palm leaf mats used to bale fish (FAO, 1970). Proctor (1972) dusted jute sacks with synergized

pyrethrins (1:16) at a rate of 1.1 g/m^2 and found that although infestation of dried Tilapia spp. by dermestids was greatly reduced the insects were able to penetrate the sacks and attack the fish. Guillon (unpublished, 1976) continued the work in Mali and proposed the use of one percent applications of either malathion or tetrachlorvinphos to treat the palm leaf mats used for packaging the fish. The use of malathion for this purpose in Mali has subsequently gained acceptance (Anon, 1984a).

The only recent investigational work on applying insecticide to packaging materials was conducted in Nigeria by Taylor (1981) who evaluated pirimiphosmethyl, chlorpyrifos-methyl, and permethrin applications to woven fibre matting at a rate of 0.5 g/m^2. Permethrin was the most effective but appeared too expensive for rural use.

SUMMARY

Examination of the available literature revealed a general lack of in-depth evaluations in which consumer safety has been given an emphasis equal to the efficacy of the insecticide and in which full technical details of methods and materials have been recorded.

Additionally it is difficult to make comparisons between many of the studies because they frequently involve different species of insects or different formulations of an insecticide. Similarly whilst much of the earlier investigational work was conducted in temperate climates the greatest need at present is to develop safe and effective treatments for use in tropical and sub-tropical areas.

Faced with the very real problems of insect infestation and lack of sound technical advice it has proved extremely difficult for many Fisheries Departments to properly address the subject and formulate satisfactory policies.

The initial work on blowfly control was based on an assumption that the treatments of pyrethrins did not present a hazard to consumers. It was only later that analytical techniques adequate to determine residues in fish were developed. The data from Malawi cast doubt on whether synergized pyrethrin treatments can achieve good control of blowflies without exceeding the MRLs. The presence of piperonyl butoxide possibly presents a greater problem in this respect than the active ingredient itself. The most promising of the other insecticides appears to be pirimiphos-methyl for which an MRL on fish has recently been recommended.

The early studies on the control of beetles also centred on the use of synergized pyrethrins and many trials have been conducted. However, residues have been determined on only a few occasions and in each instance they have been found to exceed the MRL. Tetrachlorvinphos has been very successfully in Mali but as yet no MRL has been recommended for this insecticide. Pirimiphos-methyl has a recommended MRL and has been shown in several countries to be safe and effective in use. Of the other insecticides the synthetic pyrethroids deltamethrin and permethrin appear the most promising. Interest in treating the packaging material has declined in recent years.

Although synergized pyrethrins and pirimiphos-methyl are the only insecticides which have recommended MRLs on fish, only the latter appears to be capable of providing safe and effective control of both blowflies and beetles under tropical and sub-tropical conditions. To overcome problems associated with the availability of insecticides in some countries and the possible future problem of insect resistance it is important to fully evaluate other insecticides in order to generate data so that additional MRLs on dried fish can be established. Many of the studies in the past have been conducted on an ad hoc and fragmented basis. It is important that future work be more comprehensive and definitive. It should be undertaken through properly planned programmes in which data on both efficacy and residues are developed simultaneously.

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APPENDIX 1

Insects		Common Names
Order Coleoptera (beetles)		
Family Anobiidae		
Lasioderma serricorne (F.)		- cigarette beetle, tobacco beetle.
Family Cleridae		
Necrobia ruficollis (F.)		- red-shouldered ham beetle.
Necrobia rufipes (Degeer)		- red-legged ham beetle, copra beetle.
Family Dermestidae		
Dermestes ater	Degeer	- black larder beetle, hide beetle.
Dermestes coarctatus	Harold	- (none).
Dermestes frischii	Kugelann	- fish beetle, hide beetle.
Dermestes maculatus	Degeer	- hide beetle, leather beetle.
Order Diptera (files)		
Family Calliphoridae		
Calliphora terraenovae	(Macq.)	- blowfly
Calliphora vicina	Rob.-Desv.	- blowfly
Chrysomya marginalis	Wied.	- blowfly
Chrysomya megacephala	(F.)	- oriental latrine fly
Lucilia cuprina	(Wied.)	- sheep blowfly
Lucilia sericata	(Mg.)	- green blowfly
Family Sarcophagidae		
Wohlfartia sp.		- blowfly

APPENDIX 2

Insecticides

Group	Mammalian Toxicity (L.D.50 Acute oral rats[1/]) (mg/kg)	Source
Organo-chlorine		
Chlorbicyclen	200-400	d
DDT	113-118	b
Gamma HCH (Lindane)	88-270	b
HCH (BHC)	500-1 000	a
Organo-phosphorus		
Chlorpyrifos	135-163	b
Chlorpyrifos-methyl	1 630-2 140	b
Coumaphos	16-41	c
Demeton	3-12	b
Diazinon	300-400	b
Dichlorvos	56-108	b
Dimethoate	500-680	b
Fenchlorphos	1 740	b
Fenitrothion	800	b
Iodofenphos	2 100	b
Malathion	2 800	b
Methacrifos	678	b
Phosalone	120-170	b
Pirimiphos-methyl	2 050	b
Tetrachlorvinphos	4 000-5 000	b
Trichlorphon	560-630	b
Carbamate		
Propoxur	90-128	b
Pyrethroids[2/]		
Alphacypermethrin	79-5 000	e
Bioallethrin	425-875	b
Bioresmethrin	7 070-8 000	b
Cypermethrin	251-4 123	b
Deltamethrin	135-5 000	b
Permethrin	430-4 000	b
Natural Pyrethrins	584-900	
Synergist		
Piperonyl butoxide	7 500	b

Insecticides

Group	Mammalian Toxicity (L.D.50 Acute oral rats[1/]) (mg/kg)	Source
Insect Repellent		
Dipropyl pyridine -2, 5-dicarboxylate (no common name)	5 230-7 230	b
Chitin Inhibitor		
Diflubenzuron	4 640	b

a/ A lethal dose for fifty per cent of the test organisms (rats). Expressed as milligrammes of insecticide per kilogramme of body weight, mg/kg

b/ The L.D.50 for pyrethroids varies greatly depending upon insecticide carrier and experimental conditions

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